Improvements Which Simplify Receiver Operation and Decibels

LESSON ND-27

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IMPROVEMENTS WHICH SIMPLIFY RECEIVER OPERATION AND DECIBELS

LESSON ND-27

In this lesson you will study some of the important improvements which have been made in basic radio circuits in the past few years. These are improvements which are more or less standard in the usual radio set of today.

First you will study an improvemen which is closely associated with AVC. When a receiver is equipped with AVC, it is difficult for the *human ear* to follow changes in sound intensities, because the *sound level* does not change appreciably. Thus, without some *positive means* of knowing when a carrier wave is tuned to exact resonance, the average person is likely to tune the receiver to a point near resonance—thus, distortion is introduced. This distortion is brought about due to the fact that the receiver amplifies *one side-band frequency* of the carrier wave more than the other. To avoid mistuning the receiver, various *tuning aids* have been developed which indicate when the receiver is tuned to exact resonance.

You will remember in previous lessons it was brought out that each radio station sends out its signals on a certain carrier or high frequency. The actual signals which result in sound waves are low or audio frequencies, and these, in turn, are superimposed on the carrier high frequency. The audio frequencies, you will recall, are called modulation frequencies.

Thus, in a transmitted wave there is a combination of carrier and modulation frequencies which extend from zero to 5000 cycles (5 KC) each side of the carrier frequency. If the carrier frequency is 1000 KC, its higher range of modulation frequencies will extend from 1000 KC up to a limit of 1005 KC. If the modulation frequencies went higher than 1005 KC, they would be extending over into the range of the next frequency channel of 1010 KC. The modulation frequencies above the carrier frequency are often called *the upper range of side-band frequencies.* The modulation frequencies below the carrier are called the lower range of side-band frequencies.

From this brief explanation you can see that if both side-band frequencies are to be *amplified equally,* the receiver must be tuned to *exactly* 1000 KC if the latter should happen to be the resonant frequency. Any deviation from exact resonance on either side of 1000 KC will simply mean that one side-band frequency will be amplified more than the other. Because of this unevenness or unbalance of amplification, distortion will be very evident.

This is not merely a matter of cutting down certain frequencies of the modulation, but of actual interference of the two side-bands causing quite noticeable and serious distortion. The lowest modu-

lation frequencies from sidebands nearest the carrier frequency are first lost on *detuning*. The remaining higher modulation frequencies become increasingly distorted under this condition.

Now, almost everyone can distinguish between high quality reception and distortion, yet few people realize the cause of it. They are more likely to blame the receiver which they are using, as they do not realize the significance of the detuning effect. Before the advent of AVC, the *sound volume level* furnished a fair index to the person tuning the receiver to resonance at least to within a few hundred cycles. Automatic volume control by its very operation almost completely does away with this tuning index because as the tuned circuits are tuned more and more away from resonance, the sensitivity of the receiver rises, making the output almost the same as at resonance. With a strong local carrier, this might be true as much as 40 or 50 KC off resonance. Commonly with such a carrier, the average person can tune 10 KC off resonance and barely detect a reduction in volume. However, the quality of reception is very much impaired by this off resonance tuning. Again the person tuning the receiver may sense the change in quality, but he may not know which way to tune or restore good quality. With AVC he no longer has the volume of the output to serve as an index for resonance. Since AVC is now standard on practically all modern receivers, numerous methods have been developed for overcoming its tuning difficulties. Among the first of these was the tuning meter —usually nothing more than a milliammeter.

RESONANCE INDICATORS

A good *electrical index of resonance* is the plate current of the amplifying tubes controlled by the AVC. Since, with maximum signal strength the bias will be maximum, the *plate current* of all of the AVC controlled tubes will be minimum at resonance *regardless of the actual speaker output.*

While the change in plate current of one RF or IF tube would operate a resonance indicator, usually all of the plate circuits whose current is automatically controlled are connected to a single B+ supply lead, and this is connected to the power unit *through a DC milliameter.* In this way, a more rugged meter may be used for the purpose, and, by making use of the average changes of two or three tubes under control, a more definite action may be obtained.

Figure 1 shows a circuit in which three tubes are AVC controlled: the RF tube, first detector and IF tube. These tubes are of the super control type as required for AVC, and their plates are fed through the DC meter (M).

If each of these tubes have a maximum plate current of 8.2 milliamperes at a minimum bias of −3 volts, the total plate current will be 24.6 ma. Thus, an 0-25 DC milliammeter may be used as a resonance indicator. When the receiver is first turned on the meter needle will rise to maximum deflection in twenty or thirty seconds and remain there until a signal starts to be received. As the

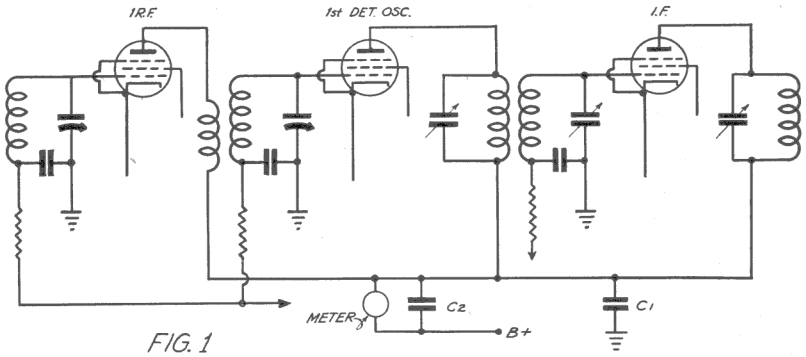


FIG. 1

tuned circuits are brought into resonance, the AVC voltage will be developed and applied to the grids of the controlled tubes as a negative bias voltage. This will reduce the plate current of all controlled tubes, *and at resonance this total plate current will be minimum.*

Rather than having the meter read in milliamperes, it is calibrated in any convenient arbitrary marking and it reads *in reverse to* the scale usually employed for a milliammeter. The meter is mounted (upside down) on the receiver control panel, and its shows a deflection to the right or *up-scale as its current reduces.* When the receiver power is turned off, the needle of the meter remains in its maximum up-scale position which is exactly its zero position for current flow. The meter is reversed in this way to facilitate tuning. It is more natural to tune to a maximum swing of the needle than to a minimum. In this case, a maximum deflection indicates minimum current—it also indicates true resonance. This meter may also be placed in the cathode circuit of one or more controlled tubes. It is in series with and composes part of the value of the cathode resistor.

In this way, very accurate tuning may be obtained. If the receiver is tuned out of resonance, the volume of the signal may be maintained as far away as 10 or 15 KC, but the meter deflection will drop rapidly, indicating the off-resonance condition.

A condenser C1 in Fig. 1) is placed across the meter (.1 to .5 mfd.) to by-pass any high frequency current which may arise in the plate circuits. Frequently the meter is by-passed with a condenser at a point beyond the meter in the B+ circuit. However, there is one objection to this method of connection because if the condenser becomes shorted, the meter winding may burn out if the by-pass condenser shorts. If it does not short in this position, it merely makes the meter temporarily inoperative until the condenser is replaced.

Graphically, the detuning action may be represented as in Fig. 2. At some point in frequency about 5 KC off-resonance such as the dotted line X-Y, the signal strength may drop perhaps only a few per cent and would go unnoticed as measured by the ear. The meter needle, however, would indicate to perhaps within 15% or 20% of its

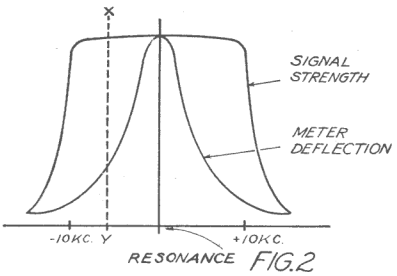


FIG.2

maximum deflection or nearly maximum current. Although the volume for all practical purposes would be the same, the signal would be *considerably distorted,* and the meter needle would accurately indicate it.

THE SHADOWGRAPH

The meter principle may be applied to a movable vane or needle which may be used to *interrupt a beam of light*—this giving an indication of resonance. Such an in-instrument, called the shadowgraph, is shown in diagram form in Fig. 3. A coil (A) carries the combined plate current of two, three or more AVC controlled tubes. The magnetism thus produced will be *inversely proportional* to the signal strength; or, when the signal is maximum, *the magnetism is minimum.* Thus plate current reduces and, of course, the magnetism reduces due to less plate current. Referring again to Fig. 3, an ordinary pilot light (B) is mounted in the center of coil (A) and a permanent magnet (C) in ring form with a small air gap is mounted concentrically in front of the coil (A). In reference to Fig. 3, you are looking down on the instrument from the top, and the iron disc (D) appears as a line—the pivot on which it rotates is vertical. The vane (E) is a small fiber or metal plate non-magnetic but opaque and made fast to the disc (D) which has a small square aperture *cut in its center.*

As the current in the coil (A) rises, it will tend to turn disc (D) in line with its field which, of course, is along its axis. The vane or needle turns with the disc, and, in so doing, *cuts out a portion* of the central area of light passing through the aperture in (D). A screen (F) on which the light falls shows a shadow from vane E. The thinner the shadow line on the screen, the nearer the receiver is tuned to resonance. Of course, the wider the shadow line, the farther away the tuning is from resonance.

When the current through (A) reduces due to a signal increase, the permanent magnet (C) draws the disc (D) back into its own plane where the magnetism is strongest. This narrows the shadow as the vane (E) is now placed in line with the light. The shadow on the screen (F) is now due to the width of the vane only.

Because of the shape of the light beam, the outer end of the vane from its pivot is somewhat longer than the inner end. This permits equal expansion of the shadow either side of the center.

To prevent serious light reflection, the light beam emerging from

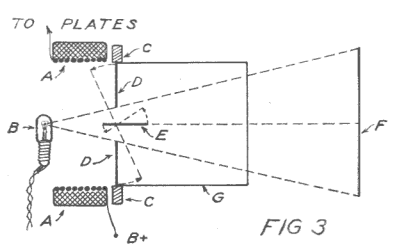


FIG 3

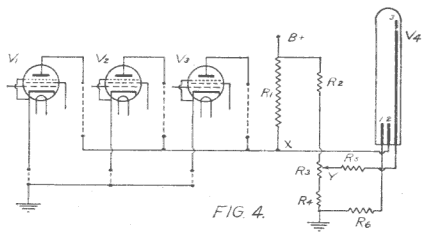


FIG. 4.

the disc (D) is enclosed in a tubular material (G), and the entire appartus is housed in a wedge-shaped metal box.

The screen of this assembly is mounted on the receiver panel and the *width of the shadow* on it serves as an index in tuning the receiver. Resonance, of course, is is indicated by the narrowest shadow.

NEON GAS RESONANCE INDICATOR

Just as the plate circuit of a tube (in the study of AVC) was used as one arm of a potentiometer so may two or three tubes be used in the same way. In this case, a voltage variation indicates resonance rather than a current variation. The circuit of Fig. 4 shows one way to employ this principle.

Tubes V1, V2 and V3 of Fig. 4 may be any three AVC controlled tubes. They are supplied with plate voltage through a resistor R1, having a fairly high resistance value. A voltage divider consisting of sections R2, R3 and R4 with R3 in the form of a potentiometer, serving to provide other needed voltages.

Any sealed tube with suitable electrodes which is gas filled or has a trace of gas in it will become luminous when 45 or 50 volts are impressed on it. No filament or cathode is necessary as emission will take place from any metal element which is 45 or 50 volts below the potential of any metal part within the gas. The atoms or molecules of gas become broken up into *electrons and ions* when the gas pressure is sufficiently low so that one ion may not materially affect an adjacent one. At low pressure (partial vacuum) they are sufficiently spaced so that they may not affect one another materially in this way. At higher pressure, a higher voltage is required for ionization and at higher voltage, the degree or amount of ionization is more intense. The ionization process causes radiation of light from the gas and the color of this light depends on the properties of the gas itself. Neon, when ionized, will emit a red-orange light with which you are probably already familiar. A large portion of present-day illuminated advertising is done by gas tubes using neon or other gases or a combination of gases at low pressure.

A long neon tube, such as V4 in Fig. 4, has three cold electrodes in the form of vertical round tungsten or molybdenum wires, numbered in this case 1, 2 and 3. The tube is generally about ½ inch in diameter and 2½ to 3 inches long (average).

Conductors 1 and 2 are maintained at a high difference of potential, as 1 is connected through R6 to ground and 3 is connected to the common plate supply through R5, R3 and R2. Normally B+ is about 350 volts and point X is 250 volts positive—there being about a 100 volt drop across R1, due to the combined plate currents of the three tubes. Point Y may be ad-

justed to approximately 250 volts due to the variable resistance R3. Electrodes 1 and 2 which are only ½ inch long keep a constant glow in the base of the lamp when the receiver is turned on. The gas between and around these electrodes remains luminous all of the time. When the receiver is tuned to *resonance,* the plate current is *minimum* and the voltage at X rises, for example, to 325 volts. This is about 75 volts higher than point Y which remains at 250 volts and further ionization builds up between electrodes 2 and 3 in the neon tube V4.

The ionization rises higher up the length of the tall electrode No. 3 as the potential of electrode No. 2 rises above that of No. 3. Thus, when a station is tuned to resonance, the neon tube is at full brilliance throughout its entire length. Many of the older type receivers use this form of resonance indication.

BLINKER TUNING

Keep in mind the relation of the plate current of controlled tubes to the signal strength and refer to Fig. 5.

A reactance (choke coil with an iron core in this case) is placed in series with the pilot light circuit which illuminates the tuning dial of a receiver. A shell type core is used for this reactance and a winding is placed on the center leg. It, in turn, is connected in series with the plate circuits of the controlled tubes. Both of the outer legs of the metal core are wound with wire and the two windings are connected in series aiding. Without considering the center winding, the

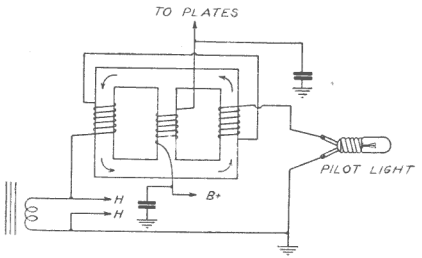


FIG. 5

reactance of this device to current flow in the pilot light circuit is so high that the pilot light almost goes out. However, when sufficient plate current flows through the center leg, the iron core is *saturated with magnetism* and the reactance to AC will be greatly lowered. You will recall having studied about magnetic saturation in a former lesson. When the magnetism in an iron core reaches a certain critical value, further increases in current flow do not increase the magnetism proportionally and finally a value is reached where no amount of current increase will increase the magnetism.

This may be compared to removing the iron core as far as its effect on the pilot light is concerned. It is quite obvious that when resonance is reached with minimum plate current, the reactance of the pilot light circuit is increased, and, as the receiver operator tunes from one station to another, the pilot light will *blink* as a station is passed and remain at *minimum illumination* when on resonance. A very sharp resonance point is thus established.

The shell core transformer is chosen so that two reactance windings can be wound in such a way as to not have a transformer action.

Otherwise the pilot light current would produce a large alternating voltage in the plate circuits of the controlled tubes, resulting in serious hum. The way they are wound, the pilot light windings cannot induce magnetism in the center leg. The plate circuit winding is by-passed just as a tuning meter or shadowgraph would be by-passed with a condenser. This method of resonance indication did not prove to be popular and, therefore, was not used in many receivers.

COLORAMA TUNING

Another application of the saturated reactance principle is used in what is popularly called Colorama Tuning. The system is shown in Fig. 6. A pilot light winding on the power transformer supplies about 20 volts to a network of pilot lights partly through a small *saturation reactance*, as explained for Fig. 5. When the reactance is saturated by heavy plate current flow in the central winding, the three green lights are practically shorted out of the circuit and the greater portion of the voltage is impressed across the four red pilot lights in a series-parallel connection. The dial is, therefore, illumined red. When resonance with a strong station is reached, the plate current of the tubes under AVC control will be greatly reduced, thus removing the saturation magnetism from the pilot light magnetic circuit. This time the three green lights in series are supplied with the greater voltage, and the voltage drop across the red lights is not sufficient to make them light. The action of this circuit may be somewhat clarified by inspection of an equivalent resistance circuit as in Fig. 7. All of the pilot lights and the reactance circuits have been replaced with resistors in this circuit. As XL, in Fig. 7, is increased it takes on a very high value and most of the voltage drop will be across the resistor marked green. If XL is low in value or shorted, all of the voltage of the supply will be placed across the red lights—thus they will light. In this type of circuit, green indicates resonance and red indicates an off-resonance condition.

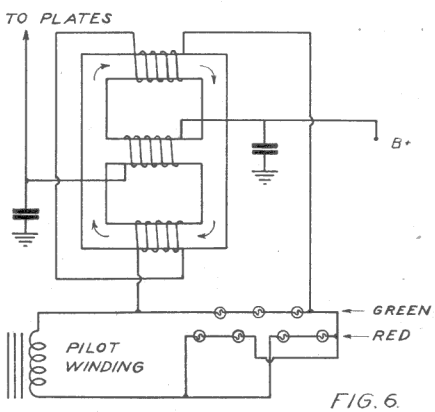


FIG. 6.

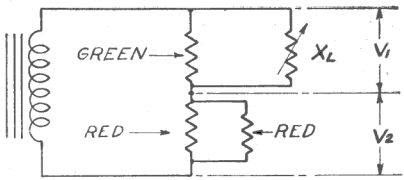


FIG 7.

THE ELECTRIC OR MAGIC EYE TUBE

Since the eye tube will operate directly from the AVC voltage, it makes a most *accurate* resonance indicator. This device is an ordi-

nary triode tube of the glass type. Typical examples are the 6AD6G, 6AF6G, 6AF7G, 6X6G, 6AB5, 6E5, 6G5, 6U5, 6H5, 6N5, 6T5, 2E5, 1629, etc. The circuit of the electric eye with its connection to the AVC circuit is shown in Fig. 8. It has a *dome* envelope and mounted in the dome is a conical metallic target electrode "T" coated with a fluorescent material. The cathode "K" extends through the center of this target so that its emission of electrons to the inside surface of the conical target will become luminous. Essentially the same coating may be used as for regular cathode ray oscilloscope tubes. The plate of the triode section "P" is fitted with a molybdenum wire parallel to the cathode and close to it extending also through a hole in the center of the target. It is called the *ray control electrode* as its potential or voltage with respect to the cathode will determine the amount of area on the concave target surface which will remain luminous. When the voltage of the triode plate and hence that of the control electrode increases due to an increase in negative voltage on the control grid, *more* of the target area becomes luminous. The location of the ray control electrode in the center of the cone shaped target makes it cast an electronic shadow on the target, taking the form of a wedge-shaped circle sector varying in width according to potential. A high voltage will, of course, cast a small shadow and a low voltage (on the ray control electrode) casts a wide area shadow.

Point X of Fig. 8 is so chosen that approximately 1/3 of the voltage occurring at Y will be obtained. This voltage is, of course, more negative than ground or zero potential and is proportional to the signal strength. A voltage divider consisting of R1 and R2 is placed across the AVC circuit to obtain a voltage which will operate the control grid of the electric eye. Note that this network and the tube are the only addition to the ordinary AVC circuit. The control grid of the electric eye tube is completely shielded.

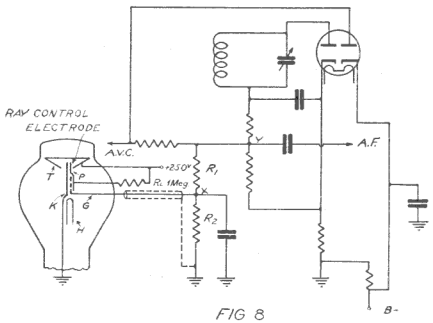


FIG 8

Now when resonance is approached with the tuning circuits, the AVC negative voltage builds up, increasing the bias on the electric eye control grid and narrowing its target shadow as explained. In this way accurate tuning may be obtained with AVC.

There are several types of electric eye tubes, and it is quite likely that others will be developed. They have slightly different characteristics. Full details of the operation and characteristic of the 6E5 are shown in Fig. 9. Note the different shadow widths below the graph of Fig. 9. These represent the type of shadow which appear on the end of the tube for various values of AVC. The curve Ep of the graph indicates the nature of the plate voltage change for the

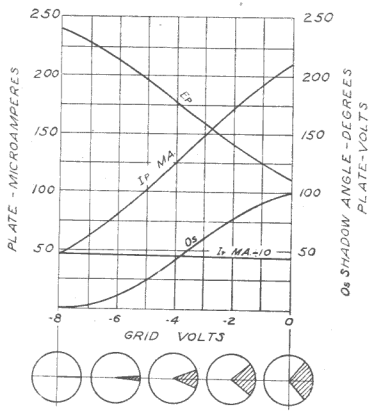


FIG. 9

eye tube. Curve Ip in Fig. 9 is the plate current which is proportional to the grid voltage and to the shadow angle. Curve Os is the shadow angle in degrees—referring to the right-hand scale—and Ip may be regarded as the target in milliamperes divided by 10. Below the graph, five views of the target's shaded area are shown. Note that these correspond to 0, —2, —4, —6, and —8 volts on the control grid.

BEACON TUNING

By far the most precise method of indicating resonance is accomplished by means of the beacon oscillator. It has been used infrequently since the earliest days of radio but has never been extremely popular, probably because of the difficulty of understanding its operation or the lack of knowledge of its operation. Fig. 10 shows the circuit of a typical beacon oscillator which is simply an unmodulated oscillator tuned exactly to the intermediate frequency of a superhetrodyne. To get the proper action with this circuit, it is necessary to couple the beacon oscillator circuit to the IF or second detector circuit. This may be done by connecting a small condenser (.0001 mfd.) between the plate or grid of the beacon oscillator and the second detector grid or diode or to the last IF plate circuit. Another method of coupling may be employed by connecting a small condenser between the beacon oscillator and the cathode of the IF or second detector tube if these are not grounded. By employing either method of coupling, the beacon oscillator is permitted to feed energy to the IF or second detector circuit.

In tuning, as resonance is approached, the energy fed to the IF circuit from the beacon oscillator forms a beat frequency with the IF. This is *reproduced in the speaker as an audibue tone.* The object in tuning is to adjust the controls until the beat frequency sound disappears from the speaker. This is called *zero frequency beating.*

When the pre-selector tuning system is adjusted to zero beat, as determined by the audible tone from the speaker, exact resonance has been reached. Usually a push button is used so that the beacon oscillator may be used only while tuning—it being released upon arriving at zero beat. Disregarding the possible frequency drift in the beacon frequency which may be compensated out by an equal drift

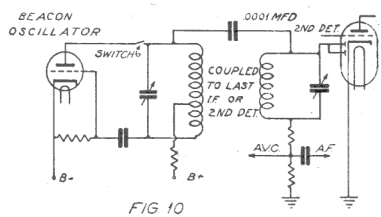


FIG 10

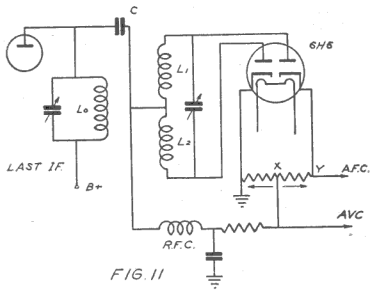


FIG. 11

in the IF oscillator circuit, resonance within 20 cycles may be acquired with this system. Ordinarily no automatic apparatus could possibly give a result this good.

AUTOMATIC FREQUENCY CONTROL

One of the most complicated devices for acquiring accurate tuning is the automatic frequency control circuit. It makes use of the very obvious principle that if the RF and oscillator tuning condensers are somewhat out of tune, the oscillator frequency may be automatically shifted so that the proper IF beat note will result. An electrical network is arranged which will automatically shift the oscillator frequency either up or down until the correct beat note for the IF amplifier will be formed.

Figure 11 is an example of how this system works. Part of the actual AFC circuit in Fig. 11 is used to select a positive or negative voltage with respect to ground for *application to the oscillator*, making it increase or decrease *in frequency* by a system to be explained later on.

The 6H6 diode tube and its input circuit is called the *discriminator* and may be simplified as in Fig. 12. In this figure the two halves of the IF secondary in Fig. 11 have been substituted with two AC generators. It is perfectly proper to assume that they are generators because voltage is magnetically induced into L1 and L2 from L0 in Fig. 11. At the center tap in Fig. 11 an additional voltage is coupled into both L1 and L2 by a condenser, C, which is connected to the top of the IF primary L0. This arrangement is equivalent to two generator voltages—(1) Ec and EL1 in series with diode plate D1, and (2) Ec and EL2 in series with diode plate D2 in Fig. 12. The combination of Ec and EL1 through rectification produces the DC voltage E1 across load R1 and the combination of Ec and EL2 produces E2 across load R2 (note that each cathode has its own load in Fig. 12).

To make this study definite, assume that each of the generators in Fig. 12 is producing a peak voltage of 35 volts. At resonance, the relationship between the three voltages will be as indicated by the curves in Fig. 13. Now the total voltage applied to D1, Fig. 12, will be the sum of Ec and EL1 because these two are in series with it. EL2 does not enter into this relation at all. Note that EL1 and EL2 are exactly 180° out of phase—that is, when one diode plate is positive with respect to the point Z in Fig. 12, the other plate

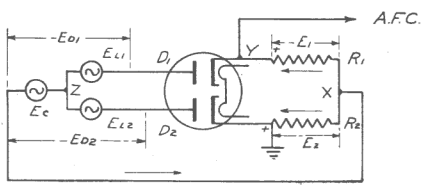


FIG. 12

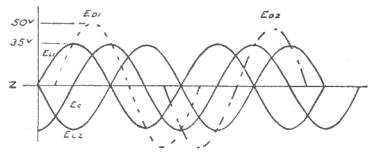


FIG 13

is an equal amount negative. You know this same principle to be true for transformers, as, for example, a power transformer using a full-wave rectifier or two half-wave rectifiers. The voltage, due to the capacity coupling (see condenser C of Fig. 11) is 90° out of phase with both EL1 and EL2, as it is fed through a condenser. When the primary current of L0 in Fig. 11 is zero, the induced voltage in L1 and L2 is maximum, but the voltage fed through condenser C is minimum so this is why Ec is out of phase with that of L1 and L2.

The voltage applied to D1 of Fig. 12 is the sum of Ec and EL1 —so if they are added a total of Ed1 is obtained as in Fig. 13. As an example, a total of 50 volts peak AC might be applied to D1 of Fig. 12 and this is rectified and is impressed as E1 across the load R1. Likewise, if the voltages of Ec and EL2 are added, the value Ed2 will be obtained which may also be 50 volts, but it will be impressed across R2 as voltage E2 when rectified. This will make the *negative end* of load R2 or point X of Fig. 12, 50 volts negative, assuming no loss due to rectification with respect to ground as the cathode of D2 is grounded. Point X in Fig. 12 is used for AVC and audio voltages just as for any detector. Point Y is, of course, 50 volts more positive than point X. The value 50 volts has been used in the foregoing as a figurative value to illustrate the circuit action. Actually there is, of course, a loss in voltage due to rectification.

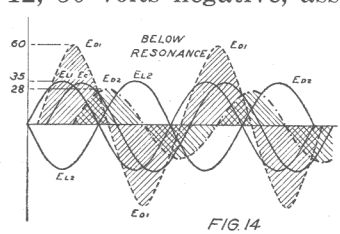


FIG 14

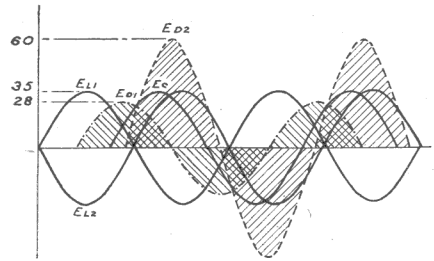


FIG. 15

Below resonance the relationship between the three voltages changes as in Fig. 14. Ec comes nearer in phase with EL1 so that the sum of these two (Ed1) is larger than 50 volts. Ec also goes further out of phase with EL2, the sum producing somewhat less than 35 volts as at Ed2. Above resonance the phase shift of Ec as compared to the other two is the opposite and this time (Fig. 15) the sum of Ec and EL1 is less than 35 volts and Ec and EL2 is somewhat greater than 35 volts.

This action means that there is a voltage at point Y of Fig. 12 which varies according to Fig. 16. Below resonance there is a rising positive voltage and above resonance there is an increasing negative voltage. Notice that both the net voltages of Fig. 16 increase as tuning progresses away from resonance. This brings up the sub-

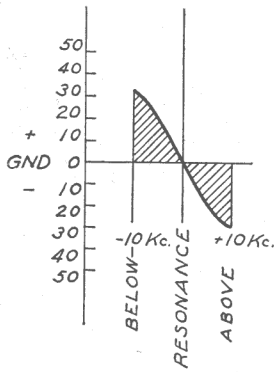


FIG. 16

ject of how *these voltages may be used to increase the oscillator frequency* when the IF signal is below resonance of the IF amplifier and to *decrease it when above resonance.* This action would result in correcting for slight inherent detuning of the oscillator and RF circuits. Refer to the circuit of Fig. 17 and note the oscillator circuit at the right. In this case a pentode oscillator tube is used although a triode or tetrode would also serve the same purpose with alterations in the circuit design. The complete tuned grid circuit of this oscillator consists of the main variable tuning condenser C1, the high frequency trimmer C2, the low frequency padder C3 and the isolating condenser C4 to complete the RF circuit through the lower section of the grid coil L2.

Both L1 and L2 of Fig. 17 form part of the tuned grid circuit and L3 is the plate or feed-back coil. In some circuits the AFC tube controls the entire oscillator grid coil. This is simply a matter for the designer to choose as a less complete control of the entire coil is equivalent to the more complete control of a smaller section of the coil. In this case, the L2 section of the grid coil is used for control (that part of the circuit to which a control voltage is applied to change the frequency of the oscillator tube).

Variations of the inductance of L2 by *real or artificial* means may change the oscillator frequency, and it is the function of the AFC tube to control this—to maintain the correct oscillator frequency at all times by introducing an artificial change in the inductance value of L2.

In shunt with inductance L2 of Fig. 17 from point X to ground is a resistor and the plate circuit of a pentode tube—the AFC tube. Except for its ordinary plate or *output capacity* its effect would ordinarily be that of a pure resistance across the coil L2. Note that the AFC plate is supplied with plate

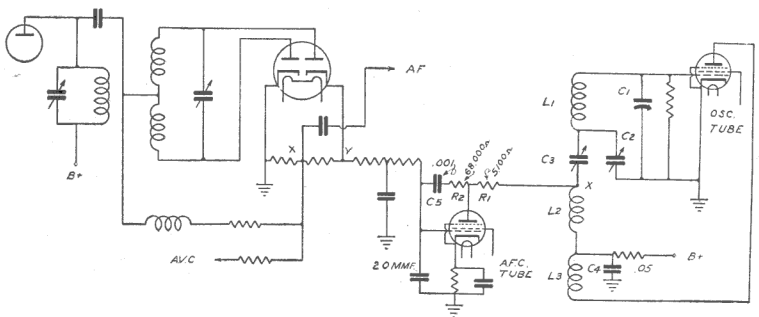


FIG 17

voltage from the same source as the oscillator and draws a current depending on its average grid bias.

Acting as a pure resistance or, in fact, as a constant capacity, the AFC tube *could not vary the oscillator frequency* but the high frequency voltage developed across L2 through oscillation is supplied to the *AFC grid* through R1, R2 and C5. You know that the plate voltage variations in a tube will be inverse or opposite to the grid voltage variations and hence the voltage fed to the grid will not be the same as that delivered by the plate. By selecting the proper values of parts, it is possible to *shift the phase* of the voltage across L2 with respect to the current through it. *This determines its reactance and by changing its reactance in this way its apparent inductance is artificially changed —thus changing the frequency.* A greater negative voltage will be be formed by the IF being above resonance. When below resonance the AFC grid will be driven more positive, *the total oscillator inductance* will be reduced and its frequency will be increased. Note that the double diode circuit of Fig. 17 is the same as the one which was described in Figs. 11 and 12. Voltages developed by it are, of course, fed to the grid of the AFC tube.

As the oscillator frequency shifts one way or the other, it shifts towards resonance, thus lowering its own applied AFC voltage so that it can never reach exact resonance but can always come within a few per cent of it. If the detuning is large, around 5000 cycles, the oscillator may be forced to within about 300 or 400 cycles of resonance, but if the detuning is small or around 1000 cycles, the oscillator will shift to within 70 to 80 cycles of the proper frequency.

Another similar frequency control system has been developed and used as in Fig. 18. The connection of the diode and discriminator circuits are somewhat the same as in Fig. 17 although the AVC and audio signals make use of entirely separate circuits not shown in Fig. 18. The discriminator loads of R1 and R2 and the two voltages V1 and V2 created by the discriminator action are impressed across the resistors R3 and R4. At resonance the voltages are identical for reasons explained in connection with the former circuit. Below resonance one voltage is greater than normal and the other less. The circuits are completed to ground through R3 and R4. A filter consisting of C1-C2-R5-R6 serves to produce pure DC from the discriminator terminating in C3 and C4. The combinations of R7-C5 and R8-C6 allow a varying voltage to be fed to the two grids of the AFC tube from the loads R1 and

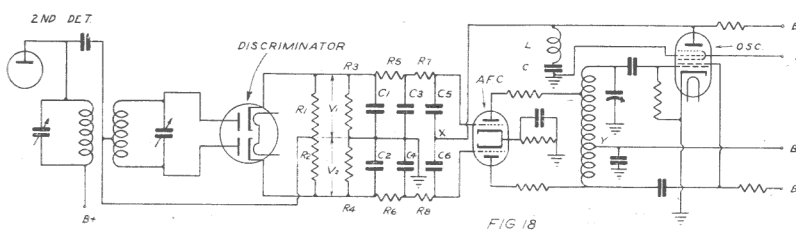


FIG 18

R2. Note that this is equivalent to a regular resistance coupled amplifier where there is a bias, grid resistor and condenser.

The oscillator plate is connected to point X so that some of the oscillator voltage is fed to each grid of the AFC tube through C5 and C6. Point Y at the oscillator grid coil is the point of constant potential and the plates of the AFC tube are connected an equal number of turns either side of this point. Voltages developed at these points due to oscillation are equal and opposite in phase and remain so while both plates of the AFC are drawing the same current. Furthermore, when they have the same bias and are excited with the same grid impulse, the resulting plate impulses will exactly cancel one another. However, if one grid of the AFC tube is more negative (due to the action of the double diode circuit) than the other, the energy from the oscillator plate will feed more energy back to one point on the coil than the other. By the proper adjustment of the circuit L-C, a lagging voltage is fed to X which will make the oscillator increase its frequency when the bias of one AFC grid is high and decrease it when low. As long as the grids are biased equally, no matter what the bias is, the oscillator frequency will remain unchanged.

NOISE SUPPRESSOR CIRCUIT

Almost without exception no problem in receiver design has been as baffling or has been given as much attention as that of the elimination of static or electrical interference accompanying the received signals. If such interference has an equivalent energy level to the signal there seems to be no possible way to eliminate it from the circuit. There is one method, however, that has been partially successful although it has not met with wide commercial use. The circuit is shown in Fig. 19. It will be well to define the nature of certain types of interference resulting in noise so that the operation of this circuit may be fully appreciated.

To form a sound wave, an RF impulse must have a *time duration* or there must be a succession of waves rather than one wave. Otherwise, the impulse can scarcely be heard, or, if it is sufficiently rapid, it cannot be heard at all. When a bell is struck with a hammer, the initial stroke sets the bell into vibration, and, if it vibrates at, say, 1000 cycles, obviously in one minute 60×1000 or 60,000 waves will be sent out. Depending on the size and quality of the bell, it may ring for one minute or more before its vibration stops. Even if the initial vibration of any substance producing sound is stopped, in most cases the sound will continue due to reflection, reverberation or natural resonance of other objects. This action is just as true with electritrical circuits which are in tune with one frequency or another. An electrical impulse will excite or electrically *strike* the circuit and electrical oscillation will *continue* for a short time afterwards.

Graphically, an electrical impulse causing static interference would look something like curve A in Fig. 20. This would set up an electrical wave such as curve B

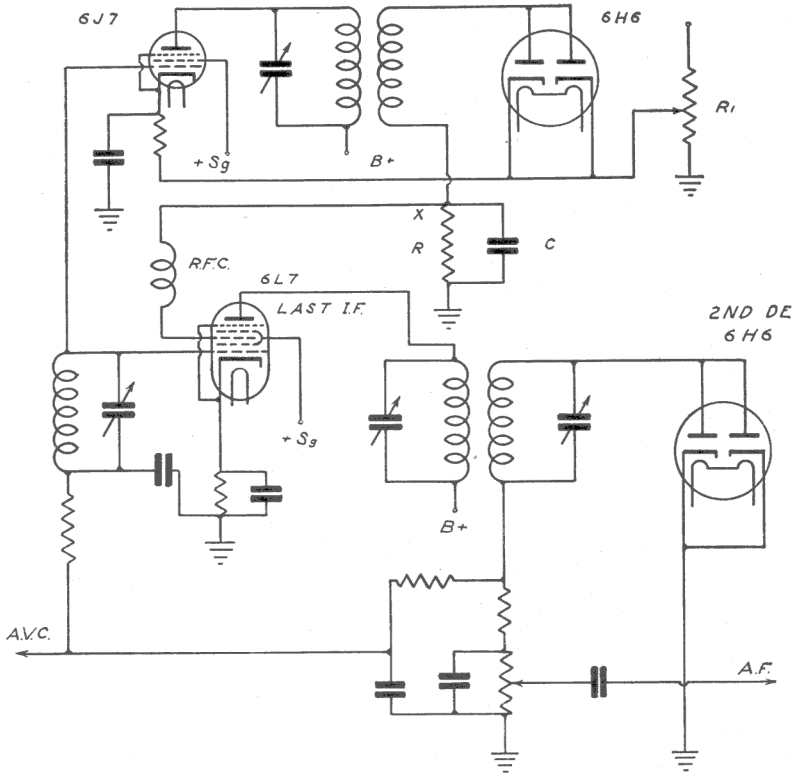


FIG. 19

and the relatively long time that the energy stays in the circuit would allow it to be transmitted to the second detector where it would be rectified, producing the sound impulse C. A number of such impulses would produce a tone such as you have undoubtedly heard in a radio speaker due to an electric motor or generator running near it. An auto ignition system will induce such a tone in an improperly installed receiver, or an oil burner or electrical refrigerators or a vacuum cleaner will cause similar trouble.

Because of the nature of each interference, it may be eliminated by suppressing the original impulse before it goes far enough into the tuned circuits to produce any sustained oscillation. The circuit of Fig. 19 is designed to accomplish this result.

A 6L7 tube is used as the last IF amplifier—usually the only IF amplifier in small receivers. It is a double control grid pentode with the grids shielded from one another. Each grid may have somewhat the same control action on the plate current in the tube. The grid nearest the cathode is used for amplifying the IF or the signal. The input of the 6L7 is divided, part being fed to a 6J7 sharp cut-off pentode similar to the 57, 77 and 6C7 tubes. This feeds the signal into a regular diode rectifier which may be biased by means of

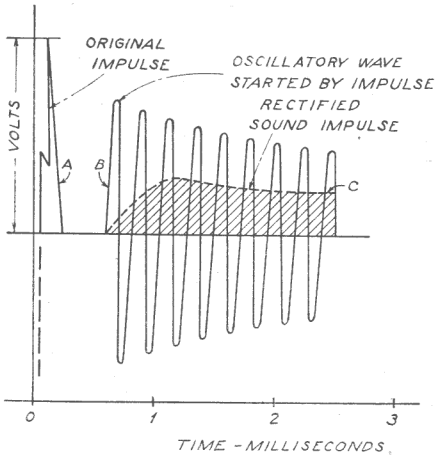


FIG. 20

the setting of R1 to start rectification at any normal signal level. The negative DC voltage produced by the action of this circuit at X is fed through the radio frequency choke RFC to the second control grid of the 6L7. Note the similarity of this action to ordinary AVC circuits. The main difference in this circuit is that the condenser C is very small and that there is no filter in the circuit. It is, therefore, a quick acting AVC. In one ten-thousandth of a second the receiver may be entirely blocked due to a high negative charge on the second control grid of the 6L7 tube and then immediately assume normal sensitivity.

The setting of R1 in Fig. 20 is adjusted so that at the normal signal level it will prevent rectification in the 6H6 tube. Obviously, if it did rectify each signal peak, certain parts of the signal would be cut out because of the blocking action. However, when a static or interfering impulse is received only slightly greater than the signal, *the noise silencing circuit will come into action.* Now this action is so fast that the impulse is cut out, the signal momemtarily stopped and immediately continues. Although cutting into the regular signal, the ear cannot detect this *empty gap* in the reproduced sound because it has such a short duration. If you heard a tone at 2000 cycles and but one cycle was eliminated completely, you would never know the difference. Of course, if too much of the sound or its electrical equivalent is eliminated, there will be a noticeable difference, but it is very rarely that this is the case.

This system can do nothing with interfering impulses which are equal to or below the signal level. Only those which rise above it are eliminated. While not complete in its control of interference, it is a means to an end. This circuit has had its widest application in amateur radio receivers and for reception of code signals where high quality of reception is not always necessary.

MANUAL VOLUME CONTROL

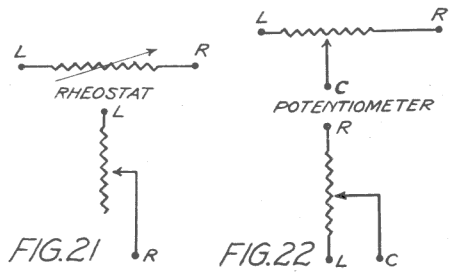
There are two essential controls for every type of radio. These are (1) a control for tuning from one frequency to another and (2 a control for regulating the speaker sound level. There are other convenient controls which make for ease in tuning and for adjusting tone quality and for turning the radio on and off. The on-off switch may be a part of the volume or tone control mechanism. It is a unit usually mounted on the back side of either the tone or volume control. The turning mechanism is usually arranged so that the first

movement of the control knob turns on the switch and further movement of the control knob varies a resistor element which may be arranged to control either volume or tone. In the reverse operation, the first movement of the control knob reduces volume or tone control to zero and the last movement of it turns the on-off switch to the off position. Tone controls will be described in a later lesson, and the remainder of this lesson will describe volume controls and the Decibel—a unit of measurement for sound or gain levels.

There are other less essential controls on many radio receivers, but these are mainly the convenience type of control to aid in tuning, for tone, noise control, etc. In other lessons brief mention has been made of manual volume controls so you should be familiar with them to some extent.

Manual volume controls are needed principally because in a given location the signal strength of various radio stations varies from just a few microvolts on up to .5 volt or more, depending on receiver location and power rating of the station sending out the signal. If it were not for this effect, fixed volume controls could be used—in fact, in some installations where a single frequency is to be received at a definite volume level, a fixed type of volume control is commonly used.

Manual volume controls in nearly all cases are of the *variable resistance* type. There are two standard types, (1) having two terminals, this type often being called a *rheostat* and (2) a three terminal type, often called a *potentiometer*. Regardless of the number of terminals on the control, it will have one terminal which is variable—that is, the resistance connecting to this terminal has a variable value depending on the position of the control knob. The symbols for several types of volume controls or variable resistances are shown in Figs. 21, 22 and 23. In Fig. 21, the rheostat, two terminal type, is shown. The symbol may be drawn in a vertical or horizontal position, and the same is true for those symbols shown in Figs. 22 and 23. Note the use of the letters L and R in the three figures. The letter L means that as the control knob is turned to the *left*, the volume decreases. The letter R means that as the control knob is turned to the *right*, the volume increases. The letter C in Figs. 22 and 23 indicate the *center* or variable terminal of the potentiometer. The symbols of Fig. 23 are a variation of the basic potentiometer of Fig. 22. Besides the variable terminal C in Fig. 23, the resistor element may have one or two fixed terminals such as R1 and R2. These points usually connect to tone compensation circuits, or they may be used for degenerative effects as will be explained in a later lesson. Sometives a potentiometer (three terminal control) is used as



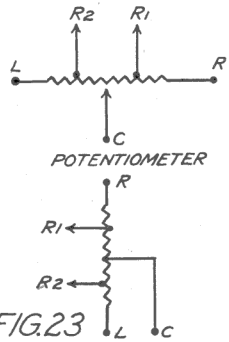


FIG.23

a rheostat (two terminal control). When this is desired, connections are made to terminals L and C (Fig. 22) with terminal R being free or disconnected. This will effectively form the type of rheostat shown in Fig. 21.

TAPER OF CONTROLS

The *taper* of a volume control is one of its most important ratings if not the most important. A wide variation in resistance value is often permissible from the rated value provided the volume control has the proper taper. You may ask what is meant by taper. To appreciate its purpose and definition, it is well to consider first how the human ear reacts to sound. The ear will not recognize sound changes (particularly small changes) in a linear manner. By this is meant, if the sound at a given level is doubled, the ear will not recognize the increase as twice the level of that used as a reference. The same is true for a proportionate decrease in sound. The ear, therefore, is not a linear mechanism. It will recognize sound level changes by a percentage increase or decrease or more technically it will recognize sound changes on a logarithmic scale rather than a linear scale. There is a certain minimum change in sound level the ear will recognize, and any change less than this minimum will not be detected. This minimum has been found to be 12.2%. All of this simply means that per degree of rotation for a volume control the rate at which the resistance changes must be in accord with the characteristics of the ear. Another lesson in the SAR Service Course treats this principle more fully with respect to volume control replacements. Suffice it to say at this time the rate at which the resistance of a volume control increases or decreases is called its *taper*. As used here, the word taper is comparable to the way a sharpened pencil tapers off to a fine point—that is, beginning from the body of a pencil, its size gradually tapers down to a fine writing point. Comparably speaking, the resistance of a volume control tapers from a high to a progressively lower value in accordance with the characteristics of the ear. In most cases, a potentiometer form of control is used similar to Figs. 22 or 23. If C in these two figures is considered to be exactly in the center of the resistance element and most of the resistance value is between terminals R and C, the volume control is said to have a left hand taper—that is, the resistance between L and C has been tapered more than that between C and R. An example of a 500,000 ohm control would be one having 50,000 ohms between L and C with 450,000 ohms between C and R. If the conditions were reversed with 450,000 ohms between L and C and 50,000 ohms between C and R, the control would have a right hand taper.

In modern radio sets, the rheostat or two terminal control is not used very much anymore except in tone control circuits which are to be taken up in a later lesson. It, too, may have either a right or left hand taper, depending on the purpose of the control. In most of your volume control work, you will be more concerned with the potentiometer form of control. Since this involves the practical angle of replacement repair work further discussion of volume control replacement will be left to a later lesson where adequate space can be devoted to it.

DECIBELS

Several of the lessons in the SAR Course following this one will deal with tone controls, volume controls, sound amplification, etc. This requires working with sound levels and their unit of measurement. If you will refer to your SAR Math Book, you will find a full mathematical discussion of the decibel (db) unit which is used as a measure of gain or loss. Because the action of a volume control is to increase or decrease the strength of a signal, its quivalent action is to give a gain or loss. It sometimes becomes necessary to know the value of this gain or loss in some basic unit of measurement, and that is where the decibel comes into use. Many audio volume control units in public address systems, transmitters, sound motion pictures, output meters for tuning adjustments, etc., are calibrated directly in units of plus or minus db, meaning units of gain or loss. Different sound levels are used as a reference in gain or loss measurements. The most common reference level in sound work is 6 milliwatts (.006 watt) which has a value equal to zero db. In broadcast work, the zero reference level is 1 milliwatt (.001) and the unit of measurement is VU, meaning volume unit.

Your SAR Math Book shows that a voltage or current gain or loss in terms of db units is equal to:

$$\text{db for voltage} = 20 \log \frac{E1}{E2}$$

and in terms of current it is equal to:

$$\text{db for current} = 20 \log \frac{I1}{I2}$$

where E1 or I1 is equal to one value of voltage or current and E2 or I2 is equal to another value of voltage or current. The arrangement $\frac{E1}{E2}$ or $\frac{I1}{I2}$ means that the ratio of one value to the other is being found. Thus, for example, if E1 or I1 is equal to 25 and E2 or I2 is equal to 10, then their ratio is $\frac{25}{10}$ or 2.5. The log of 2.5 is .39794, and the answer in db units is $20 \times .39794$ or 7.85. This, of course, represents a gain and the value 7.85 should be preceded by a + sign. Should it have been a loss, for instance, a reduction in voltage from 25 to 10, the db loss would be −7.85.

Where power values alone are being dealth with, the formula is practically the same with P being substituted for E or I and multiplication of the logarithm by 10 instead of 20. It is written as follows:

$$\text{db} = 10 \log \frac{P1}{P2}$$

where P1 equals one power value in watts and P2 the other power value in watts.

Now refer to Fig. 24 to see what significance all of this has with reference to a standard left hand taper volume control of 500,000 ohms. Note this control has 80,000 ohms tapered between L and C with 420,000 ohms tapered between C and R. Note, also, this control has been divided into 32 divisions reading from right to left. These divisions are linear or spaced equally apart. The value of resistance between divisions is not linear but rather varies logarithmically. This is done so that equal changes of the volume control knob will produce equal changes in the sound volume or level. If a sound level is doubled, the ear does not accept it as twice as loud as before. The human ear in its response to power increases does not increase as the power itself increases, but rather ear response increases according to the logarithm of the power increase. It has been determined that the smallest change that the ear can detect in value of sound level is equal to 1 decibel for a constant frequency. This refers to units of power increase or decrease in values of the power unit, the watt. Thus, if an increase is made in power from 1 to 2 decibels, the *ratio* of the increase is equal to 1.259. If the pressure of a sound wave is doubled, the ear accepts it as a 6 db increase in sound pressure and not an increase which is double that of the original sound pressure. Now just what does all of this mean in relation to the volume control of Fig. 24? It means

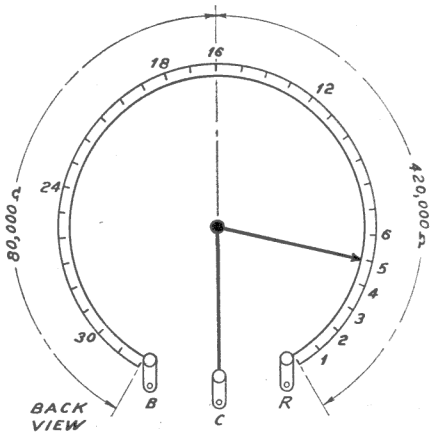


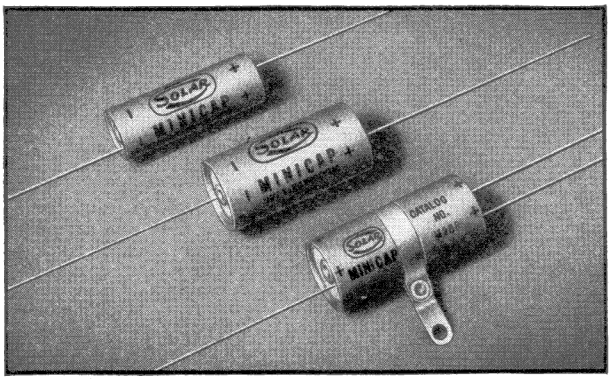
FIG. 24

that if it is to feed a *signal voltage* to the grid of the following tube in progressive steps so that equal changes of the volume control knob will produce equal sound level changes to the ear that the resistance changes between the 32 divisions must change logarithmically. In other words, the volume control knob must change in a linear manner, and the resistance of the volume control must change in a logarithmic manner.

It has been pointed out that decibels with respect to voltages are equal to:

$$db = 20 \log \frac{E1}{E2}$$

In Fig. 24 the voltage at R, is equal to 20 volts and corresponds to E1. At division 1 the voltage is equal to E2. In your SAR Math Book it was pointed out that $\frac{E1}{E2}$ or the voltage ratio was equal to 1.122 (to 3 decimal places) or equal to a change of 12.2 per cent, if there is a voltage gain. If there is a voltage loss of 1 db the voltage ratio would be equal to .8913 or a loss of 10.87 per cent. Thus, if R in Fig. 24 is equal to 20 volts, then the



Above is shown a metal encased type of the dry electrolytic condenser. Such units are hermetically sealed in metal with an outside insulated covering. They are made in capacity values up to 100 mfd., and may include one or more units. The high capacity units are made with low working voltages up to 50 volts, and the low capacity values are made with working voltages up to 525 volts. Courtesy of Solar.

voltage at division 1 (a loss from 20 volts) will be equal to 20 times the reciprocal of 1.122, and this, in turn, will be equal to $\frac{1}{1.122}$ or .8913. Thus $20\times.8913$ equals 17.82 volts. Likewise division 2 will equal $17.82\times.8913$ or 15.88 volts. Division 3 will equal $15.88\times.8913$ or 15.74 volts. In these multiplications, the answers have been carried out to two decimal places. Slightly more accuracy can be obtained by using more decimal places, but this much accuracy is not required for practical purposes. In the accompanying table all values were obtained from a calculating machine to six decimal places, but only two decimal places are included in the table. In this table the first column gives the number at each division in Fig. 24. The second column gives the voltage at that division. The third column gives the voltage drop between divisions and the fourth column gives the approximate resistance in ohms between divisions.

Now this table does not mean very much as a set of figures. However, if you study it in careful detail, much may be learned from it about volume controls and the use of decibels. For example, the voltage at 1 in Fig. 24 is 17.28 and at 2 it is 15.88. The ratio between these two voltages is $\frac{17.82}{15.88}$ or 1.122. Following the decibel rule the db value is equal to 20 log 1.122. The log of 1.122 is .049993 (from any log table). Therefore, $20\times.049993 = .99986$ db or very nearly 1 db. At the other extreme end of the table voltages for positions 31 and 32 are .56 and .5 respectively. their ratio is equal to $\frac{.56}{.5} = 1.12$ The log of 1.12 is .049218. Thus the db rating is $20\times.049218$ or .98436 db or again a figure very nearly equal to the whole number 1. From this explanation you will see that each of the divisions on the volume control of Fig. 24 gives an approximate 1 db decrease in the signal strength as the control knob is rotated. Now refer to the third column of the table (VD). This

TABLE FOR FIGURE 24

Divisions R	E1 & E2 20	VD (aprox.)	Resistance (aprox.)
1	17.82	2.17	54,367.22
2	15.88	1.93	48,455.62
3	14.15	1.72	43,186.82
4	12.61	1.53	38,490.95
5	11.24	1.37	34,305.65
6	10.02	1.22	30,575.45
7	8.93	1.09	27,250.85
8	7.96	.97	24,288.40
9	7.09	.86	21,646.93
10	6.32	.77	19,293.06
11	5.63	.68	17,195.24
12	5.02	.61	15,325.52
13	4.47	.54	13,659.11
14	3.99	.48	12,173.90
15	3.55	.43	10,850.17
16	3.17	.38	9,670.39
17	2.82	.34	8,618.88
18	2.51	.30	7,681.71
19	2.24	.27	6,846.45
20	2.00	.24	6,102.00
21	1.78	.21	5,438.50
22	1.58	.19	4,847.15
23	1.41	.17	4,320.10
24	1.26	.15	3,850.36
25	1.12	.13	3,431.69
26	1.00	.12	3,058.55
27	.89	.10	2,725.98
28	.79	.09	2,429.57
29	.70	.08	2,165.39
30	.63	.07	1,929.94
31	.56	.06	1,720.08
32 or L	.50	.06	1,533.05

gives the value of the voltage drops between db steps. Between R and 1 there is a voltage drop (VD) of 2.17 volts. With 20 volts applied to a 500,000 ohm volume control, the current through it will be equal to $\frac{20}{500{,}000}$ or .00004 ampere. If 2.17 volts exists between R and 1 and the current is .00004 ampere the resistance between R and 1 is equal to $\frac{2.17}{.00004}$ or 54,367 ohms. Between 31 and 32 the resistance is equal to 1533 ohms. Note the resistance in one case is 54,367 and the other is 1533 ohms. In both cases a change of 1 db is obtained yet the resistance values are entirely different. This principle illustrates exactly just what is meant by the taper of a volume control. It also shows the value of the db unit as a measure of gain, voltage, power, etc. Referring to the table again, note the voltage difference between divisions 3 and 2 is 1.72 volts, while between divisions 31 and 30 it is .06 volts, yet both represent a change in volume of 1 db. An increase from .56 to .63 volts is the same ratio as an increase of from 15.88 to 17.82 volts. The human ear would recognize either change as a 1 db change in sound intensity. So you should ever keep in mind that a certain number of db units in gain or loss would be meaningless in terms of voltage, current, power, etc., unless it is in reference to some other known value.

It is a long process to find the ratio of two powers, voltages or currents, look up the log of the ratio and then multiply the log by 10 or 20 in order to arrive at the db value. This process can be shortened considerably by referring to a decibel table of ratios and reading the db value directly. See the accompanying ratio tables. To find a db value, all you have to do is to get the ratio (done by dividing one unit by the other) of the two powers, voltages or currents and read the db value from the table.

Decibels Versus Power, Voltage, and Current Ratios

db	Current and Voltage Ratio		Power Ratio		db	Current and Voltage Ratio		Power Ratio	
	Gain	Loss	Gain	Loss		Gain	Loss	Gain	Loss
0.1	1.012	0.9886	1.023	0.9772	5.6	1.905	0.5248	3.631	0.2754
0.2	1.023	.9772	1.047	.9550	5.7	1.928	.5188	3.715	.2692
0.3	1.035	.9661	1.072	.9333	5.8	1.950	.5129	3.802	.2630
0.4	1.047	.9550	1.097	.9120	5.9	1.973	.5070	3.891	.2570
0.5	1.059	.9441	1.122	.8913	6.0	1.995	5012	3 981	.2512
0.6	1.072	.9333	1.148	.8710	6.1	2.018	.4958	4.074	.2455
0.7	1.084	.9226	1.175	.8511	6.2	2.042	.4898	4.169	.2399
0.8	1.097	.9120	1.202	.8318	6.3	2.065	.4842	4.266	.2344
0.9	1.109	.9016	1.230	.8128	6.4	2.089	.4786	4.365	.2291
1.0	1.122	.8913	1.259	.7943	6.5	2.114	.4732	4.467	.2239
1.1	1.135	.8811	1 288	.7763	6.6	2.138	.4677	4.571	.2188
1.2	1.148	.8710	1.318	.7586	6.7	2.163	.4624	4.677	.2138
1.3	1.162	.8610	1.349	.7413	6.8	2.188	.4571	4.786	.2089
1.4	1.175	.8511	1.380	.7244	6.9	2.213	.4519	4.898	.2042
1.5	1.189	.8414	1.413	.7080	7.0	2.239	.4467	5.012	.1995
1.6	1.202	.8318	1.445	.6918	7.1	2.265	.4416	5.129	.1950
1.7	1.216	.8222	1.479	.6761	7.2	2.291	.4365	5.248	.1906
1.8	1.230	.8128	1.514	.6607	7.3	2.317	.4315	5.370	.1862
1.9	1.245	.8035	1.549	.6457	7.4	2.344	.4266	5.495	.1820
2.0	1.259	.7943	1.585	.6310	7.5	2.371	.4217	5.623	.1778
2.1	1.274	.7852	1.622	.6166	7.6	2.399	.4169	5.754	.1738
2.2	1.288	.7763	1.660	.6026	7.7	2.427	.4121	5.888	.1698
2.3	1.303	.7674	1.698	.5888	7.8	2.455	.4074	6.026	.1660
2.4	1.318	.7586	1.738	.5754	7.9	2.483	.4027	6.166	.1622
2.5	1.334	.7499	1.778	.5623	8.0	2.512	.3981	6.310	.1585
2.6	1.349	.7413	1.820	.5495	8.1	2.541	.3936	6.457	.1549
2.7	1.365	.7328	1.862	.5370	8.2	2.570	.3891	6.607	.1514
2.8	1.380	.7244	1.905	.5248	8.3	2.600	.3846	6.761	.1479
2.9	1.396	.7161	1.950	.5129	8.4	2.630	.3802	6.918	.1445
3.0	1.413	.7080	1.995	.5012	8.5	2.661	.3758	7.079	.1413
3.1	1.429	.6998	2.042	.4898	8.6	2.692	.3715	7.244	.1380
3.2	1.445	.6918	2.089	.4786	8.7	2.723	.3673	7.413	.1349
3.3	1.462	.6839	2.138	.4677	8.8	2.754	.3631	7.586	.1318
3.4	1.479	.6761	2.188	.4571	8.9	2.786	.3589	7.762	.1288
3.5	1.496	.6683	2.239	.4467	9.0	2.818	.3548	7.943	.1259
3.6	1.514	.6607	2.291	.4365	9.1	2.851	.3508	8.128	.1230
3.7	1.531	.6531	2.344	.4266	9.2	2.884	.3467	8.318	.1202
3.8	1.549	.6457	2.399	.4169	9.3	2.917	.3428	8.511	.1175
3.9	1.567	.6383	2.455	.4074	9.4	2.951	.3389	8.710	.1148
4.0	1.585	.6310	2.512	.3981	9.5	2.985	.3350	8.913	.1122
4.1	1.603	.6237	2.570	.3891	9.6	3.020	.3311	9.120	.1097
4.2	1.622	.6166	2.630	.3802	9.7	3.055	.3273	9.333	.1072
4.3	1.641	.6095	2.692	.3715	9.8	3.090	.3236	9.550	.1047
4.4	1.660	.6026	2.754	.3631	9.9	3.126	.3199	9.772	.1023
4.5	1.679	.5957	2.818	.3548	10.0	3.162	.3162	10.000	.1000
4.6	1.698	.5888	2.884	.3467	10.1	3.199	.3126	10.23	.0977
4.7	1.718	.5821	2.951	.3389	10.2	3.236	.3090	10.47	.0955
4.8	1.738	.5754	3.020	.3311	10.3	3.273	.3055	10.72	.0933
4.9	1.758	.5689	3.090	.3236	10.4	3.311	.3020	10.97	.0912
5.0	1.778	.5623	3.162	.3162	10.5	3.350	.2985	11.22	.0891
5.1	1.799	.5559	3.236	.3090	10.6	3.388	.2951	11.48	.0871
5.2	1.820	.5495	3.311	.3020	10.7	3.428	.2917	11.75	.0851
5.3	1.841	.5433	3.388	.2951	10.8	3.467	.2884	12.02	.0832
5.4	1.862	.5370	3.467	.2884	10.9	3.508	.2851	12.30	.0813
5.5	1.884	.5309	3.548	.2818	11.0	3.548	.2818	12.59	.0794

Decibels Versus Power, Voltage, and Current Ratios—*Continued*

db	Current and Voltage Ratio		Power Ratio		db	Current and Voltage Ratio		Power Ratio	
	Gain	Loss	Gain	Loss		Gain	Loss	Gain	Loss
11.1	3.589	0.2786	12.88	0.0776	16.1	6.383	0.1566	40.74	0.0245
11.2	3.631	.2754	13.18	.0759	16.2	6.457	.1549	41.69	.0239
11.3	3.673	.2723	13.49	.0741	16.3	6.531	.1531	42.66	.0234
11.4	3.715	.2692	13.81	.0724	16.4	6.607	.1514	43.65	.0229
11.5	3.758	.2661	14.13	.0708	16.5	6.683	.1496	44.67	.0224
11.6	3.802	.2630	14.45	.0692	16.6	6.761	.1479	45.71	.0219
11.7	3.846	.2600	14.79	.0676	16.7	6.839	.1462	46.77	.0214
11.8	3.891	.2570	15.14	.0661	16.8	6.918	.1445	47.86	.0209
11.9	3.936	.2541	15.49	.0646	16.9	6.998	.1429	48.98	.0204
12.0	3.981	.2512	15.85	.0631	17.0	7.079	.1413	50.12	.0200
12.1	4.027	.2483	16.22	.0617	17.1	7.161	.1396	51.29	.0195
12.2	4.074	.2455	16.60	.0603	17.2	7.244	.1380	52.43	.0191
12.3	4.121	.2427	16.98	.0589	17.3	7.328	.1365	53.70	.0186
12.4	4.169	.2399	17.38	.0575	17.4	7.413	.1349	54.96	.0182
12.5	4.217	.2371	17.78	.0562	17.5	7.499	.1334	56.23	.0178
12.6	4.266	.2344	18.20	.0550	17.6	7.586	.1318	57.54	.0174
12.7	4.315	.2317	18.62	.0537	17.7	7.674	.1303	58.88	.0170
12.8	4.365	.2291	19.05	.0525	17.8	7.762	.1288	60.26	.0166
12.9	4.416	.2265	19.50	.0513	17.9	7.852	.1273	61.66	.0162
13.0	4.467	.2239	19.95	.0501	18.0	7.943	.1259	63.10	.0158
13.1	4.519	.2213	20.42	.0490	18.1	8.035	.1245	64.57	.0155
13.2	4.571	.2188	20.89	.0479	18.2	8.128	.1230	66.07	.0151
13.3	4.624	.2163	21.38	.0468	18.3	8.222	.1216	67.61	.0148
13.4	4.677	.2138	21.88	.0457	18.4	8.318	.1202	69.18	.0145
13.5	4.732	.2113	22.39	.0447	18.5	8.414	.1189	70.80	.0141
13.6	4.786	.2089	22.91	.0437	18.6	8.511	.1175	72.44	.0138
13.7	4.842	.2065	23.44	.0427	18.7	8.610	.1161	74.13	.0135
13.8	4.898	.2042	23.99	.0417	18.8	8.710	.1148	75.86	.0132
13.9	4.955	.2018	24.55	.0407	18.9	8.811	.1135	77.63	.0129
14.0	5.012	.1995	25.12	.0398	19.0	8.913	.1122	79.43	.0126
14.1	5.070	.1972	25.70	.0389	19.1	9.016	.1109	81.28	.0123
14.2	5.129	.1950	26.30	.0380	19.2	9.120	.1097	83.18	.0120
14.3	5.188	.1928	26.92	.0372	19.3	9.226	.1084	85.11	.0117
14.4	5.248	.1906	27.54	.0363	19.4	9.333	.1072	87.10	.0115
14.5	5.309	.1884	28.18	.0355	19.5	9.441	.1059	89.13	.0112
14.6	5.370	.1862	28.84	.0347	19.6	9.550	.1047	91.20	.0110
14.7	5.433	.1841	29.51	.0339	19.7	9.661	.1035	93.33	.0107
14.8	5.495	.1820	30.20	.0331	19.8	9.772	.1023	95.50	.0105
14.9	5.559	.1799	30.90	.0324	19.9	9.886	.1012	97.72	.0102
15.0	5.623	.1778	31.62	.0316	20.0	10.000	.1000	100.0	.0100
15.1	5.689	.1758	32.36	.0309	30.0	31.62	.0316	1,000	.0010
15.2	5.754	.1738	33.11	.0302	40.0	100.0	.0100	10^4	10^{-4}
15.3	5.821	.1718	33.88	.0295	50.0	316.2	.0032	10^5	10^{-5}
15.4	5.888	.1698	34.67	.0288	60.0	1,000.0	.0010	10^6	10^{-6}
15.5	5.957	.1679	35.48	.0282	70.0	3,162.0	.0003	10^7	10^{-7}
15.6	6.026	.1660	36.31	.0275	80.0	10,000.0	.0001	10^8	10^{-8}
15.7	6.096	.1641	37.15	.0269	90.0	31,620.0	.00003	10^9	10^{-9}
15.8	6.166	.1622	38.02	.0263	100.0	100,000.0	.00001	10^{10}	10^{-10}
15.9	6.237	.1603	38.91	.0257					
16.0	6.310	.1585	39.81	.0251					

Suppose you have a db power rating and want to know its equivalent rating in watts. This is easily done by referring to the table, obtaining the power ratio for the db rating and multiplying it by .006 (reference level). Thus the power ratio for 1 db is 1.259 and this multiplied by .006 gives .007554 or .0076 watts. 2 db would

equal 1.585 (power ratio for 2 db) times .006 or .0095 watts.

If it were a voltage or current db value involved you might want to know the exact value of the voltage or current. The only way to find this value is to know in advance the value of the voltage or current used as a reference. For instance, an amplifier is rated at 20 db with an input voltage of .25 volt. What is the value of the output voltage? The voltage ratio for 20 db is 10. Therefore, the output voltage is equal to $10 \times .25$ or 2.5 volts. If there is an 80 db increase, the voltage ratio is 10,000, and if the input is .05 volt the output is $10{,}000 \times .05$ or 500 volts. Here is another example. A volume control reduces the signal voltage -8 db from a level of 42 volts. To what value is the voltage reduced. The voltage ratio for -8 db is .3981. Thus .3981 $\times 42$ equals 16.72 volts.

Much radio equipment such as microphones, pick-up units, amplifiers, voltage controls, etc., are rated or referred to in db units. If you want to be able to appreciate all that this implies you should become thoroughly familiar with the decibel system.

MECHANICAL IMPROVEMENTS OF RECEIVERS

There are many things about a radio which are not a part of its electrical function, yet these same things can vitally affect the operation of the receiver. Such items have been steadily improved over the years, and while they are not of a technical nature, yet they are a part of every receiver, and must be taken into account if good operation is obtained. These include such things as rubber damping blocks, felt washers, antenna and ground wires, power line connections speaker plug connections, variable condenser damping blocks, control knobs, etc.

In many small radio sets where the speaker is a part of the receiver chassis its vibration will be transferred directly to the entire chassis. These vibrations in turn, will affect every other part in the receiver. Each receiver part will vibrate best at some particular frequency—the exact best vibrating frequency being determined by the mass of the part and the way it is mounted. In the larger radio set, the speaker is often mounted as a separate unit. In this type of installation, the speaker can affect the other parts of the receiver in two ways. First, vibrations can be set up through the cabinet wall, and second, vibration can be brought about through air waves which the speaker sets in motion.

Regardless of the way the vibration is set up, it will often have a peculiar effect on the operation of the receiver. The vibration may become so intense that it will vary the spacing of elements within a tube envelope. This causes them to vary at an audio rate by virtue of the fact that the original disturbance varys at an audio rate. Once the tube elements start vibrating, the capacity between the elements start changing value. This in turn modulates the plate current of the vibrating tube at a rate corresponding to the original vibration. As a result of this audio variation, a loud howl is reproduced from the speaker. This is popular-

ly known as *motorboating* because the sound it creates resembles the sound of a motorboat on the water. It is also often called microphonic trouble. The same action can be brought about by the variable condenser plates vibrating, or by other small vibrating parts.

The remedy for this trouble is to mount the receiver chassis on live rubber blocks, called damping blocks. The gang tuning condenser is often mounted on live rubber washers or grommets. In shipping the receiver from the factory to the jobber or dealer, heavy mounting screws are usually turned down tight (holding the damping blocks tight) to prevent damage during transit. Sometimes these mounting screws are not removed or loosened, and microphonic trouble is almost sure to occur. In other cases, a repair man or the owner of the receiver will remove the chassis from the cabinet and lose or otherwise destroy the rubber damping blocks. When this happens, the damping blocks will have to be replaced before satisfactory operation may be obtained. In regard to variable condensers mounted on live rubber washers, it sometimes happens that someone through ignorance will tighten the mounting screws as a condenser so mounted is supposed to be mounted loose. In other words, the condenser gang is supposed to float on live rubber. When the mounting screws are tightened, the rubber is compressed and the floating action is very much reduced. To remedy this trouble, it is only necessary to loosen the mounting screws.

Most good receivers come from the factory with felt washers between the control knobs and the cabinet. These washers slip over the control shafts and prevent the control knobs from scratching the cabinet finish. Often times someone in the owner's household or a repairman will remove control knobs and felt washers. In replacing the control knobs, the felt washers are sometimes left off the shafts. In mounting the knobs, many people will push them on the shafts as far as they will go. Not only will they fit tight in this position, making control difficult, but will also scratch the cabinet surface making a round ring on the cabinet the same size as the control knob. This may appear to be a small item, but your customers will long remember your thoughtfulness in replacing felt washers. It is often little things like this that will enable a serviceman to build a large and satisfied list of customers. You can get an assortment of felt washers from most radio part jobbers, and it is recommended that you carry them along with you in your tool kit if you intend to follow service and repair work.

There was a time when radio control knobs were simply held in place on a shaft by means of a set screw. The shaft was usually entirely round. As a consequence, often there was no reference point, indicating just where the control knob was to be fastened in place with reference to its starting and stopping positions. Then, too, on these old dials and control knobs, set screws were constantly being lost or becoming loose. Like many other parts for radio, control knobs

have also undergone improvement. Some of them are quite complicated especially where several rotating knobs or dials are fitted together and turn one within the other. This requires close machining of the rotating parts. Being made out of plastic, these parts sometimes warp or otherwise get out of shape. Sometimes sandpapering the spots where the rotating parts bind will clear up the tightness of the rotating parts, but more often the out-of-shape control knobs have to be replaced before smooth rotating action is obtained.

The principle improvement in control knobs has been in the form of a more positive means of fastening them to the shaft. Instead of using an entirely round shaft, one part of it is made flat—thus the knob can only go on the shaft in the one position, thereby establishing the correct position for the pointer. The knob itself has a half round hole in its center. This hole also has a flat side into which fits a piece of square spring steel. When the knob is pushed onto its shaft, the flat side of the shaft and the square piece of spring steel come together with considerable pressure. The spring steel pushing against the shaft and the hole wall in the center of the control knob effectively binds them together. In this way, no slipping can occur nor is a set screw required. The principle trouble with this arrangement is that someone will remove the knob form its shaft and will lose the small square of spring steel. This spring is usually loosely fitted in slots within the center hole of the knob. Thus the spring will often drop out of the knob unnoticed. For this reason you should carry a small selection of these springs along in your tool kit. They are inexpensive and easy to replace. You can no doubt get a dozen or more of these spring units from your local or nearby radio parts jobber.

One improvement made in recent years is the perfection of a built-in loop antenna for the average receiver. This does away with antenna and ground leads. The practical radio man really appreciates this improvement, because it does away with many other annoying problems. No matter how good an outside antenna and ground installation is to begin with, their owners will let them deteriorate. Thus, they develop corrosion and often become grounded. In time, therefore, many outside antenna and ground systems develop noise. Many radio owners will want to blame the radio set or the man who repairs it for the noise developed by the antenna system. That is the reason the practical radio man welcomes the loop antenna. Despite this, there are some localities and some installations where the use of an outside antenna is absolutely essential. This may be necessary because of strong interference. The procedure for taking care of this is given in other parts of your SAR Course. In connection with the loop operated receiver, it will have directional effects. If one position of the receiver does not give satisfactory operation for a given signal, rotate the position of the receiver through 360 degrees. In so doing you will find there is one

best position for a receiver where maximum signal voltage will be induced into the loop, and this, of course, will result in increased volume. For another signal from a different direction, a different position for the receiver will be required for maximum volume. It will only be necessary to move a loop operated receiver in this way when the signals are very weak or of a fading nature. This directional effect is the principle brawback to the use of the improved type loop antenna.

It is a long step in the progress of radio from early practice of battery operation to modern power line operation. Once it was necessary to have as many as eight or ten connecting wires from the batteries to the receiver. Over the years through the development of the A and B eliminators down to the present day modern AC operated radio, the number of connecting wires external to the radio set has been reduced to just two wires —those which connect to the power line. Even these two wires are encased in fabric or rubber to form just one line or cord. In some of the AC-DC radio sets, the line cord includes a third wire in the form of a resistor element to reduce the line voltage to a proper value to operate the filaments. In the case of a three wire cord, it is usually no larger than the two wire type. So, as you can see, the radio men of today have many improvements at their disposal which are taken as a matter of course, yet it has not been so long ago since these things were the plague of every radio man.

It is the same old story with regard to speakers. There have been many improvements in the mechanical arrangement and connection of these over the years. The early speakers used extremely long leads to get away from acoustical feed back and for other reasons. Gradually these were shortened until today it is the common practice in small receivers to mount the speaker right on the receiver chassis. This is no particular problem in servicing but in larger and more expensive receivers the way the speaker or speakers are wired and mounted does assume importance. This is particularly true in service and repair work. The speaker is usually mounted below the receiver chassis—often fastened over an opening in the cabinet wall. This necessitates a group of connecting wires between speaker and chassis. Sometimes these wires go through a hole in the wood shelf on which the chassis is mounted. The connecting wires will be soldered at both ends—that is, to the chassis parts and to the speaker. In order to remove both units from the cabinet for repair purposes, at least one end of these connecting wires must be unsoldered. This wastes a lot of time and makes it very unhandy for the repair man. To avoid all of this trouble an improvement was made in the form of a plug and socket. This permits the speaker to be disconnected from the chassis in a most convenient manner. The wires from the speaker terminate in the plug while those from the output tube or tubes terminate at socket terminals. If the speaker is of the electrodynamic type, the field coil leads will also be included in the

plug-socket arrangement. Thus, to remove or disconnect the speaker, all that is necessary is to simply pull on the speaker plug in much the same way that a vacuum tube is removed from its socket.

Another improvement in the ease by which a part can be removed from the chassis is the plug-in type electrolytic condenser. The condenser is mounted on a base similar to that employed for vacuum tubes. It fits into a socket and is just as easy to replace as a tube.

Various other plug-in type connections are now employed in radio sets. This is particularly true in large sets such as those which employ multiple speakers, phonograph pick-up units, recorders, etc. Sometimes the connecting leads fit into small jacks and a pull on the wires involved will quickly disconnect them. A close visual examination will enable you to tell what type of connection is employed.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1. What does minimum current in a tuning meter indicate about the tuning of a receiver?

No. 2. Does the operation of a neon tuning indicator depend on current or voltage changes?

No. 3. When the plate current of one or more AVC controlled tubes is maximum and flowing through the reactance of a BLINKER tuning reactance, is the pilot light bright or dim?

No. 4. From where is the voltage obtained to operate the control grid of an electric eye tube?

No. 5. Describe the following conditions for the electric eye:

Shadow angle.....maximum or minimum
Plate voltage.....maximum or minimum
Negative grid voltage.....maximum or minimum
Plate current.....maximum or minimum

No. 6. Why is the beacon oscillator disconnected when a station is tuned to resonance?

No. 7. What is the difference between a volume control with a right hand taper and one with a left hand taper?

No. 8. In shifting the oscillator to a higher frequency, does the AFC tube require a more negative or a more positive control grid voltage?

No. 9. The ratio between two power levels shows a loss of .3311. What db rating does this represent?

No. 10. What is the basic difference between a noise suppressor circuit as in Fig. 19 and an ordinary AVC circuit?